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Long-term results of remodeling of lateral condylar prominence after lateral closed-wedge osteotomy for cubitus varus

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Background: Despite the ability of lateral closed-wedge osteotomy for cubitus varus deformity to restore carrying angle and preserve elbow motion, there have been reports of poor cosmetic appearance of the elbow because of lateral condylar prominence.

Method: We evaluated long-term results of remodeling of lateral condylar prominence after osteotomy in 11 patients (7 of the prepuberty group, 4 of the postpuberty group). The follow-up period ranged from 4.7 to 14.2 years (average, 10).

Results: The mean preoperative and postoperative lateral condylar prominence index (LCPI) of the affected elbow were −1.2% and 36%, respectively. At final follow-up, the mean LCPI of the corrected elbow was 11.1%. In the prepubertal group, the mean LCPI decreased from 41.2% after surgery to 5.2% at final follow-up, whereas it decreased from 26.8% to 21.3% in the postpubertal group. The difference in reduction between the mean postoperative LCPI and the mean LCPI at final follow-up in the prepubertal group (36%) was greater than in the postpubertal group (5.4%) ($P = .006$).

Conclusion: Lateral closed-wedge osteotomy is a relatively simple and effective procedure for correction of cubitus varus deformity before puberty, allowing cosmetically pleasing remodeling of lateral condylar prominence.

Level of evidence: Level 4.

Cubitus varus is the most common long-term complication of supracondylar fracture of the humerus in children. Although elbow function is not greatly impaired, the deformity produced is obvious, so patients or their parents often request surgical correction for cosmetic reasons. Various osteotomy techniques to correct the deformity have been described.[7,9,12,21,23] However, the timing of surgery, which osteotomy technique to use, and which internal fixation method to use remain controversial. The lateral closed-wedge osteotomy is the most widely used method to correct deformity. Despite the method's ability to restore carrying angle and preserve elbow motion, some authors have reported poor cosmetic appearance of the elbow because of lateral condylar prominence.[3,22] Most authors have reported short-term results for this procedure,[2,4,15] but to our knowledge, none have reported long-term results of remodeling of lateral condylar prominence after this procedure. Therefore, we present here long-term results of remodeling of lateral condylar prominence after lateral closed-wedge osteotomy for cubitus varus.

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Materials and methods

Between 1993 and 2003, we performed lateral closed-wedge osteotomy of the humerus for cubitus varus in 11 patients (9 boys and 2 girls). Seven patients underwent corrective osteotomy before puberty and 4 patients had corrective osteotomy after puberty. Age at corrective osteotomy ranged from 4.6 to 22.4 years (average, 12.8). The follow-up period ranged from 4.7 to 14.2 years (average, 10). Four patients had sustained a supracondylar fracture: 2 a secondary lateral condylar fracture after supracondylar fracture; 1 a refracture after supracondylar fracture; 1 a transcondylar fracture, and 3 a fracture of unknown cause. Time from injury to corrective osteotomy ranged from 10 months to 12.8 years (average, 5.1).

The average range of motion of the affected elbow was 4.1° (range, −5°-20°) in extension, 127.3° (range, 90°-145°) in flexion. There was no functional disability in 10 patients; in 1, there was severe limitation of motion. The indication for corrective osteotomy in all cases was unacceptable cosmesis, but 1 patient also had severe limitation of motion.

Preoperative assessment

Anteroposterior radiographs of both upper limbs were obtained for all patients with the elbow in full extension and the forearm in full supination. The humerus-elbow-wrist (HEW) angle was calculated for both the normal and affected sides. Valgus angulation was described as positive (+) and varus angulation as negative (−). Before surgery, the HEW angle of the affected side ranged from −10° to −30° (average, −22.5°) and the HEW angle of the normal side ranged from 4° to 18° (average, 8.5°).

We calculated the lateral condylar prominence index (LCPI) to evaluate objectively preoperative and postoperative amounts of lateral condylar prominence. The LCPI was calculated on the affected side as the difference between the measured medial and lateral widths of the bone from the longitudinal midhumeral axis, and was expressed as a percentage of the total width of the distal humerus to minimize errors from magnification and variation of the size of individual humeri (AB − BC/AC × 100) (Figure 1).

Before surgery, we determined the desired angle of correction for each patient by comparing the HEW angles of both elbows. After tracing the outline of the affected elbow from radiographs onto paper, we measured the length of wedge to be removed during osteotomy.

Surgical technique

The procedure was performed with the patient under general anesthesia and tourniquet control, using a lateral approach with about a skin incision of 3 to 4 cm in length. The lateral periosteum was incised and reflected anteriorly and posteriorly, with care taken to preserve the medial periosteum. First, a distal osteotomy was performed perpendicular to the articular surface at the upper margin of the olecranon fossa. The proximal fragment was osteomized with the measured length of wedge, leaving the medial cortex intact. The laterally based wedge bone was then removed. With the elbow extended, the wedge was closed by fracturing the medial cortex, carefully maintaining a periosteal hinge. In all cases except 1, the French technique[7] was used. One unicortical screw was inserted into the proximal lateral cortex and another into the distal lateral cortex. The wedge was closed by tightening a figure-8 wire loop around the screw heads. When needed for stability, Kirschner-wire fixation was also done. One case was fixed by cross−Kirschner wires only. After surgery, a long arm cast was applied with the elbow at 90° of flexion and the forearm in neutral rotation. Active range-of-motion exercises were started 4 or 5 weeks after surgery.

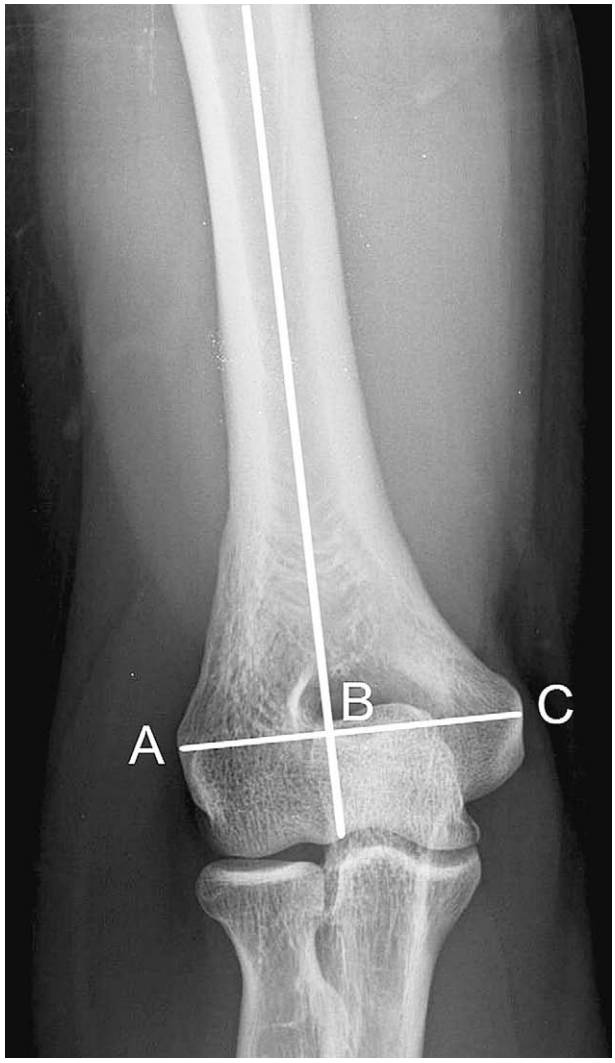

Figure 1 The lateral condylar prominence index was calculated using the following formula: (AB − BC)/AC × 100, where B is the cross-link between a line connecting the lateral prominence; A, the medial prominence; C, and the longitudinal midhumeral axis.

Evaluation of results

HEW angle, range of motion, LCPI, and complications were evaluated at preoperative, postoperative, and final evaluations. Clinical evaluation was carried out according to criteria of Bellemore et al.[3] Results were considered excellent when the difference in HEW angle for the corrected elbow versus the contralateral elbow was ≤5° and the loss of range of motion in the corrected elbow was ≤10°, good when the difference in HEW

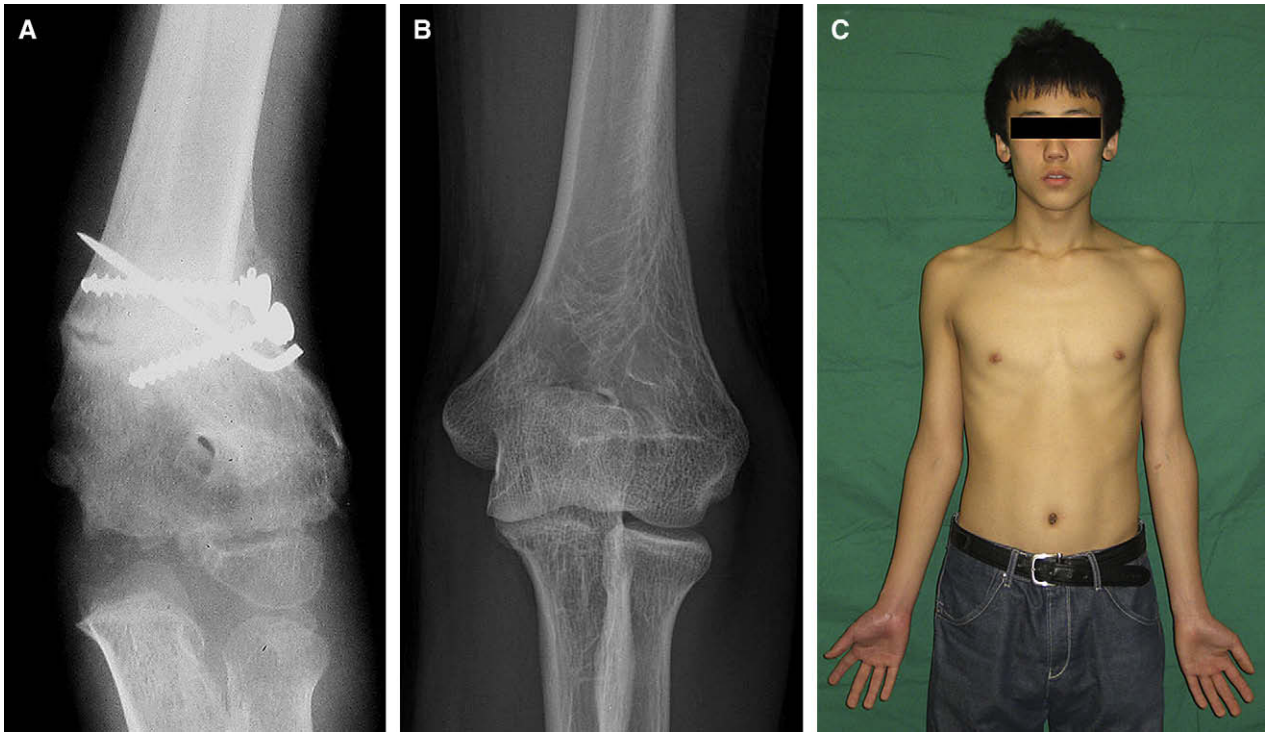

Figure 2 **A,** Anteroposterior radiograph shows lateral displacement of a distal fragment at 5 weeks after lateral closed-wedge osteotomy. **B,** Anteroposterior radiograph obtained at 8.1 years after surgery shows remodeling of the lateral condylar prominence. **C,** Surgery produced a satisfactory cosmetic result.

angle was 6° to 10° and the loss of range of motion was ≤20°, and poor when the difference in HEW angle was >10° and the loss of range of motion was >20°.

To evaluate remodeling of the lateral condylar prominence, we analyzed the LCPI by group, using the 2 independent samples *t* test. The LCPI differences between the groups were analyzed using the Mann-Whitney test. A P value $< .05$ was considered significant.

Results

Humerus-elbow-wrist (HEW) angle

The mean preoperative HEW angle in affected elbows was −22.5° (range, −10° - −30°) and the mean postoperative HEW angle was 6.4° (range, −3°-10°). At final follow-up, the mean HEW angle was 2.2° (range, −7° to 8°), and 6 patients had a difference of HEW angle between both elbows of ≤5°, 3 had difference of 6° to 10°, and 2 had a difference >10°.

Range of motion

The mean preoperative range of motion for affected elbows was 4.1° (range, −5°-20°) in extension and 127.3° (range, 90°-145°) in flexion, whereas the corresponding postoperative values were −1.1° (range −5°-3°) and 138.6° (range, 125°-150°), respectively. One elbow with severe preoperative limitation of motion at 10° in extension and 90° in flexion was restored to 0° in extension and 140° in flexion by surgery (Figure 2).

Lateral condylar prominence index

The mean preoperative and postoperative LCPI of the affected elbow were −1.2% and 36%, respectively. At final follow-up, the mean LCPI of the corrected elbow was 11.1%. In the prepubertal group, the mean LCPI decreased from 41.2% after surgery to 5.2% at final follow-up, whereas it decreased from 26.8% to 21.3% in the postpubertal group. The difference in reduction between the mean postoperative LCPI and the mean LCPI at final follow-up in the prepubertal group (36%) was greater than in the postpubertal group (5.4%) ($P = .006$) (Figure 3).

Clinical results and complications

There were 6 excellent, 3 good, and 2 poor results. In the prepubertal group, all patients had excellent results except 1 who had inadequate intraoperative correction. There were 4 complications in 6 patients: 2 patients had transient nerve palsy, 1 had combined median and ulnar nerve palsy, and 1 had ulnar nerve palsy. The complications resolved spontaneously within 4 to 5 weeks. Two patients had residual

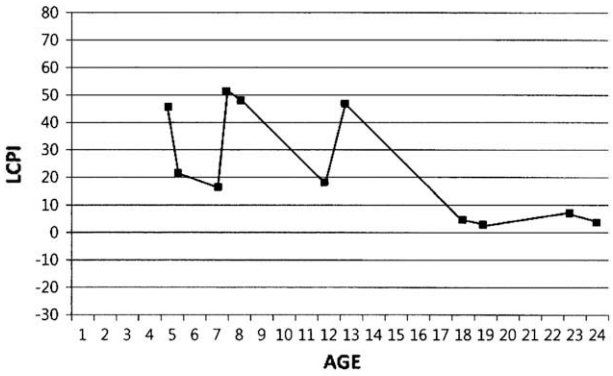

Figure 3 Graph of the difference in reduction between the mean postoperative lateral condylar prominence index (LCPI) and LCPI at final follow-up for the corrected elbow. The difference in LCPI reduction was greater in the prepubertal group than in the postpubertal group ($P = .006$).

varus deformity, 1 had inadequate intraoperative correction of varus deformity, and 1 had spontaneous recurrence of varus deformity after adequate correction. Table I details patient demographics.

Discussion

Cubitus varus is the most common long-term complication of supracondylar fracture of the humerus in children, with the reported incidence ranging from 4% to 58%.[5,10,11] The deformity is the result of malunion rather than of growth disturbance and thus is not progressive and does not improve with remodeling. Growth in humerus length is predominantly at the proximal epiphysis; perhaps there is little potential for correction by remodeling at the distal epiphysis. Although elbow function is not greatly impaired, the deformity leads many patients or their parents to request surgical correction to improve arm appearance. However, cubitus varus deformity causing traumatic lateral condylar fracture of the humerus, posterolateral rotatory instability, and poor cosmesis has been reported recently.[1,14,16,19] In our series, 2 patients with cubitus varus deformity had sustained a secondary lateral condylar fracture by repeated trauma.

The timing of corrective osteotomy remains controversial. Several authors[8,18] recommended delaying the operation until late in puberty to reduce the rate of deformity recurrence. Yet, Tien et al[20] have reported that if the distal humerus physis in not affected and the distal end of the distal humerus grows uniformly, the deformity can be corrected permanently. However, they recommend that when a direct physeal injury has occurred, clinicians always consider the possibility of late recurrence of the deformity after corrective osteotomy. Recently, some authors have recommended early correction of the deformity rather than waiting until after skeletal maturity, because the deformity is not progressive and does not improve with remodeling.[2,17,22] In our series, we found better long-term results in the prepubertal group than in the postpubertal group.

Various techniques for corrective osteotomy for cubitus varus have been described, including medial open-wedge osteotomy, dome osteotomy, step-cut osteotomy, and lateral closed-wedge osteotomy. The latter technique is the most widely used because it is relatively simple and can correct rotational deformity simultaneously; however, several authors[3,8,15] have reported poor results or significant complication rates with its use. Its complications include recurrent deformity, lateral condylar prominence, cosmetically unacceptable scarring, and nerve palsy. Despite the technique's ability to restore carrying angle and preserve elbow motion, some authors have reported that lateral condylar prominence can give rise to poor cosmetic results because hinging on the medial cortex while closing the osteotomy effectively shifts the distal fragment laterally. Bellemore et al[3] reported a lateral condylar prominence in 6 out of 27 cases in their series. Wong et al[22] reported it in 14 out of 22 cases, and noted that the prominence increased markedly when surgery was done after patients had reached the age of 12 years. They emphasized that medial displacement of the distal fragment will avoid producing a lateral condylar prominence in patients nearing skeletal maturity. Devnani[6] and Levine et al[13] also recommended complete section of the bone to allow medial displacement of the distal fragment if needed, thereby avoiding lateral condylar prominence at the elbow. Some authors have reported that dome osteotomy or step-cut osteotomy to avoid lateral condylar prominence has produced satisfactory results.[9,17,20,23] However, 2 groups of researchers reported that lateral closed-wedge osteotomy can achieve good correction of cubitus varus without significant lateral condylar prominence or unsightly scarring and produces excellent results in children young enough for remodeling to be possible.[2,21] Lateral condylar prominence is accentuated by disuse atrophy of the musculature after surgery. As upper-extremity function and strength return, the increase in muscle size helps to mask the lateral condyle.[5] Before children reach skeletal maturity, bony remodeling will also smooth the lateral contour of the humerus, deemphasizing the lateral condylar prominence. In our series, the difference in reduction between the mean postoperative LCPI and the mean LCPI at final follow-up in the prepubertal group (36%) was greater than in the postpubertal group (5.4%). All patients in the prepubertal group had excellent long-term results except for 1 in whom there was inadequate intraoperative correction. This can be explained by the fact that remodeling of a lateral condylar prominence has a higher potential for better outcome when the patient is young enough at the time of osteotomy for maturation of the deformity.

Various methods of fixation in osteotomy have been described, including Kirschner wires, Kirschner wires with figure-8 wire loop, staples, screws, screws with figure-8

Table I Patient demographics

Case	Age at surgery (years)	Time from injury to surgery (months)	Preoperative carrying angle (°)	Postoperative carrying angle (°)	Carrying angle (corrected/ normal elbow) at final follow-up	Preoperative range of motion (°)	Postoperative range of motion (°)	Preoperative LCPI (%)	Postoperative LCPI (%)	LCPI at final follow-up (%)	Difference between postoperative LCPI and LCPI at final follow-up (%)	Result	Follow-up Duration (years)	Complications
1	4.6	10	−26	9	0/2	0 to 135	0 to 140	−9.9	51.6	5.3	46.3	Excellent	11	None
2	5.1	29	−30	−3	−5/14	−5 to 130	−5 to 130	0.6	29	7.3	21.7	Poor	15	Inadequate correction
3	7	51	−10	10	8/8	10 to 125	−5 to 145	7.2	16.8	−0.2	17	Excellent	4.7	None
4	7.4	51	−25	8	8/9	0 to 145	0 to 145	13.3	47.6	−3.1	50.7	Excellent	12.1	None
5	7.9	18	−28	10	2/5	10 to 90	0 to 140	−13.1	52.1	3.3	48.8	Excellent	8.1	None
6	11.7	18	−10	10	8/10	20 to 105	0 to 140	−14.5	15.2	−4.3	19.5	Excellent	7.3	Transient median and ulnar neuropathy
7	12.6	48	−28	6	5/2	0 to 140	0 to 150	22.5	76.2	28.4	47.8	Excellent	14.2	None
8	18	132	−20	7	5/12	0 to 130	0 to 140	15.3	32.5	26.8	5.7	Good	13.1	None
9	19	72	−26	3	−2/7	0 to 135	0 to 135	−12.7	12.3	8.8	3.5	Good	7	None
10	22.8	153.6	−24	5	−7/4	5 to 135	−5 to 135	8.1	30.5	22.6	7.9	Poor	7	Recurred deformity
11	24.4	132	−20	5	2/8	5 to 130	3 to 125	−30.2	31.7	27.3	4.4	Good	10	Transient median neuropathy
Averages	12.8	5.4	−22.5	6.4	2.2			−1.2	36	11.1	24.1		10.0	

wire loop, plates, and external fixators.[3,8,13] We used fixation with a figure-8 wire loop around the heads of the screws in 10 patients and if needed, Kirschner-wires fixation was added for stability. We fixed cross−Kirschner wires only in 1 patient. There was no fixation failure in all patients; however, 1 patient in postpubertal group had spontaneous recurrence of varus deformity despite of adequate correction. The center of rotation of the distal humerus fragment is located at the medial cortex in a lateral closed-wedge osteotomy. The tightness of the medial soft tissue after the osteotomy tends to produce a strong varus movement that can lead to recurrent deformity or fixation failure if the osteotomy site is not rigidly fixed.[17] Therefore, we believe that complete osteotomy without an intact medial cortex and with more rigid fixation are warranted in patients who are nearing skeletal maturity or are older.

Lateral closed-wedge osteotomy of the humerus is a relatively simple and effective procedure for correcting cubitus varus deformity before puberty, as lateral condylar prominence can be remodeled to produce a good appearance.

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